Photovoltaic Systems: It Is Not All Sunny

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Risk Engineering

Agenda

- Outline our concerns with PV systems on roofs
- Review some available industry fire and windstorm experience
- Share some developing insights

(Photo source: Rich Gallagher, The Zurich Services Corporation)

OPENING THOUGHT

Opening thought

Technology is always advancing

- If insurers did not embrace electricity 100-years ago, we might be holding this conference by candlelight

(Photo source: Rich Gallagher, The Zurich Services Corporation)

Opening thoughts

Technology is always advancing

- If we did not embrace electricity 100-years ago, we might be holding this meeting by candlelight

- So, if we do not embrace PV systems today, what could we be missing tomorrow?

(Photo source: Rich Gallagher, The Zurich Services Corporation)

Opening thoughts

Technology is always advancing

- So, while we do have concerns with PV systems
  - Solutions are being pursued

(Photo source: Rich Gallagher, The Zurich Services Corporation)

CONCERNS WITH PV SYSTEMS ON ROOFS

Concerns with PV systems on roofs

- When a PV system is installed
  - What concerns may arise?

Roof without a PV system

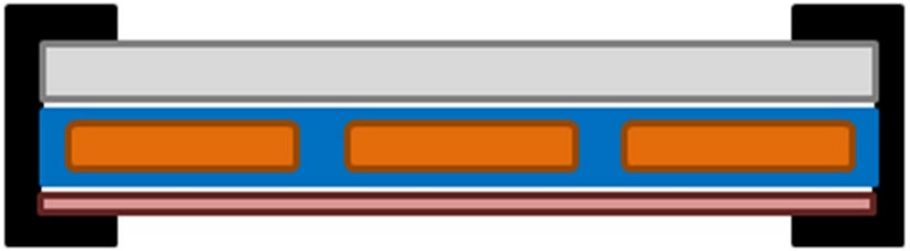
Roof with a PV system

(Photo source: Rich Gallagher, The Zurich Services Corporation)

Concerns with PV systems on roofs - #1

Fire

- Rooftop combustibles may increased
  - PV modules



- PV module noncombustible features typically include
  - Face – glass
  - Frame – aluminum
- PV module combustible features typically include
  - Encapsulant – ethyl vinyl acetate (elastomer)
  - Backsheet - polymeric

Information source:

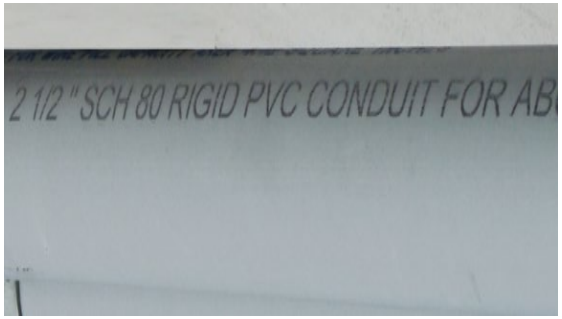
Dr. (Mani) Govindasamy TamizhMani, Joseph Kuitche. Accelerated Lifetime Testing of Photovoltaic Modules, Solar America Board for Codes and Standards, July 2013. Online.

(Image source: Rich Gallagher, The Zurich Services Corporation)

Concerns with PV systems on roofs - #1

Fire

- Rooftop combustibles may also include
  - Module junction boxes
  - Cables
  - PVC conduit
  - Combiner boxes
  - Rubber support blocks



(Photo source: Rich Gallagher, The Zurich Services Corporation)

Concerns with PV systems on roofs - #2

Fire

- PV systems may introduce ignition sources
  - Such as
    - Heating
    - Arc faults
    - Ground faults

Modules and junction boxes may experience heating

Connectors may experience arc faults

Abraded or pinched cables may experience ground faults

(Photo source: Rich Gallagher, The Zurich Services Corporation)

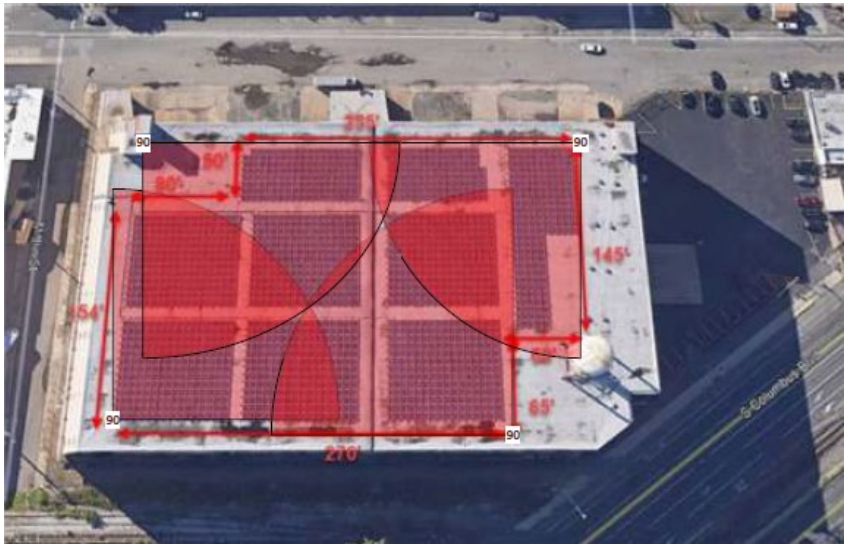
Concerns with PV systems on roofs - #3

Fire

- PV systems may introduce a need for rooftop fire detection
  - Today, people usually detect the PV fire (pedestrians, drivers, etc.)
  - Will PV fire frequency justify fixed fire detection on the roof

A possible fire detection method - Triple IR flame detectors elevated above the roof

Triple IR is a multi-spectrum, infrared detector. It is a current technology, designed for outdoor use, and is intended to provide a low rates of false alarm



Building showing possible arrangement of 4 triple IR flame detectors

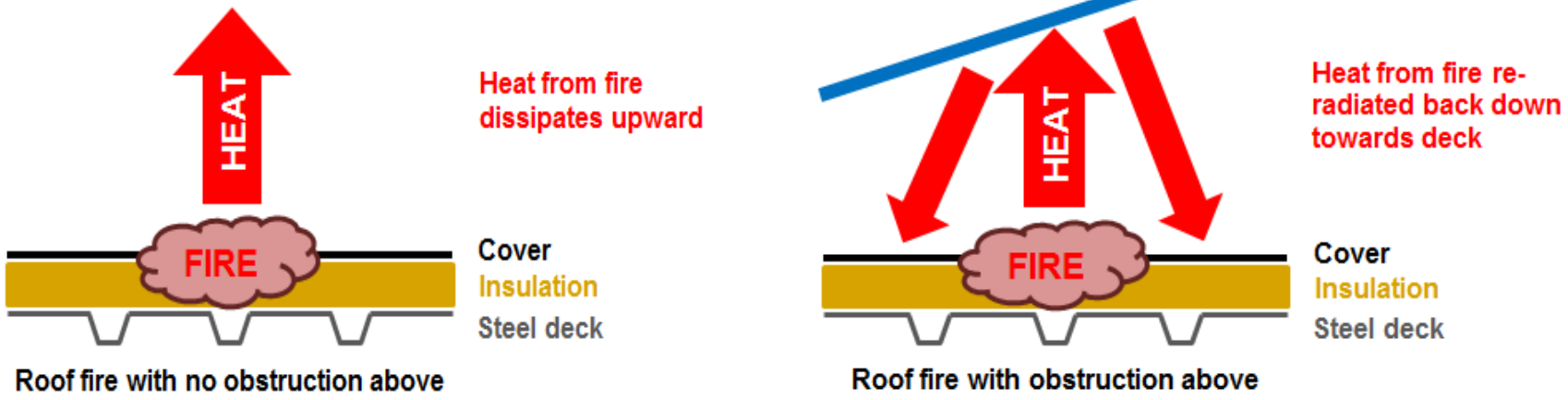
Triple IR flame detector

(Photo source: Left Rich Gallagher, The Zurich Services Corporation with mark-up by Rick Jeffress, Fike Corporation; Right, Fike Corporation)

Concerns with PV systems on roofs - #4

Fire

- PV systems may alter the fire behavior of a roof covering
  - Most roof covers should not support rapid fire propagation (the Class A roof)
    - They benefits from being in the open where heat may dissipate upward
  - With a PV system installed
    - Heat may be reflected back to the roof surface increasing fire propagation



(Image source: Rich Gallagher, The Zurich Services Corporation)

Concerns with PV systems on roofs - #5

Fire

- PV system fires may be accompanied by interior water damage
  - PV fires are expected to damage the roof cover
    - The roof cover is the weather resistant membrane that keeps rain water out
    - Fire damage may allow firefighting water to flow down into the building

How much water might the fire service use?

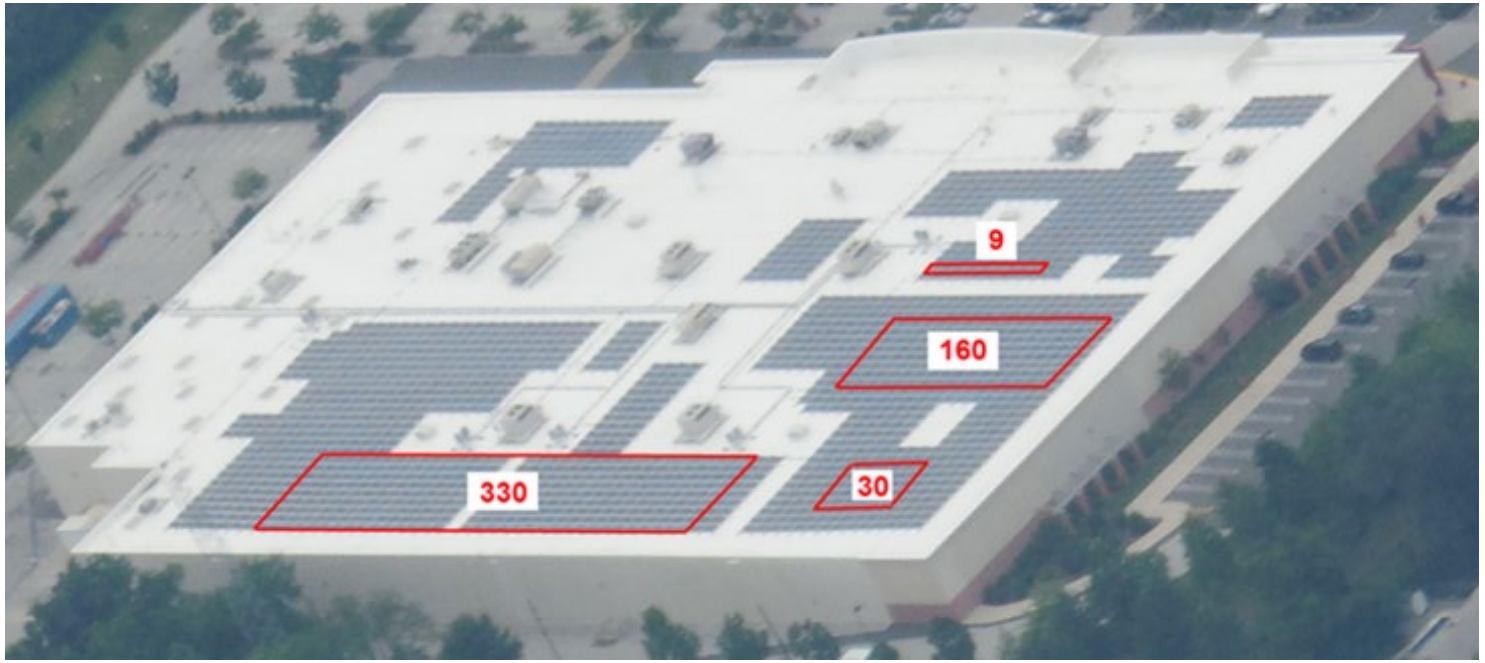
Two fire service elevated water streams may fill a home swimming pool (15,000 gallons) in 10 minutes.

(Photo source: Rich Gallagher, The Zurich Services Corporation)

Concerns with PV systems on roofs - #6

Fire

- PV system fire behavior may not be fully understood
  - Why do some fires involve 10 modules?
  - Why other fires involve 300 modules?



(Photo source: Rich Gallagher, The Zurich Services Corporation)

Concerns with PV systems on roofs - #7

Wind

- PV system wind design guidance may not be adequate
  - PV racks have reportedly moved or lifted when exposed to winds below their design wind speed

Information source:

Dregger, Phil. Field Survey - Rooftop Solar PV Performance During Hurricane Sandy. Technical Roof Services, 2012.

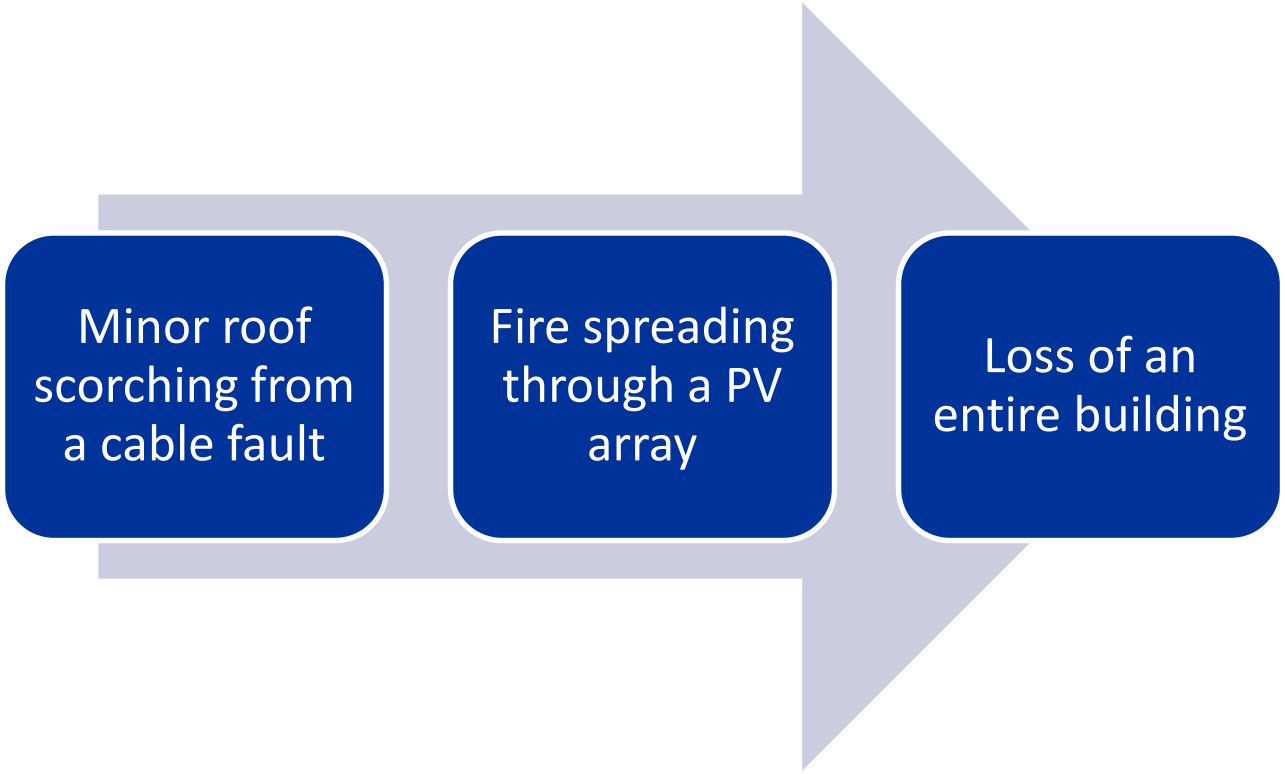
(Photo source: Rich Gallagher, The Zurich Services Corporation)

LIMITED INDUSTRY EXPERIENCE

Limited industry experience

Fire

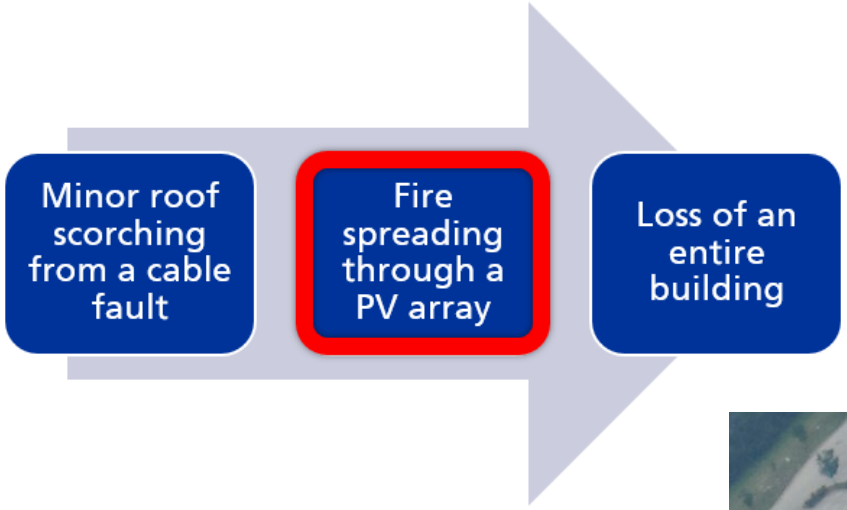
- Zurich has gathered data on over 20 PV fire events
  - There are more events, but the desired data is often incomplete
- The range of damage that is experienced includes

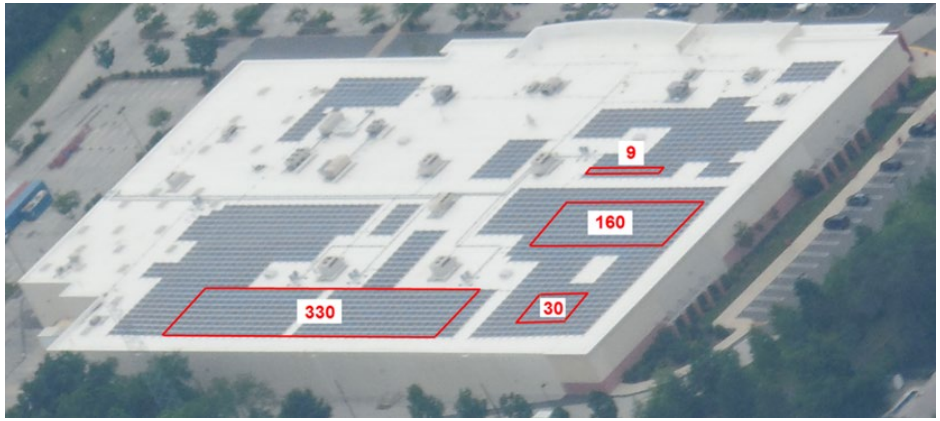


Limited industry experience

Fire

- Our focus is on our concern #6 …
  - Why do some fires involve 10 modules and others involve 300 modules?
  - What does the data indicate



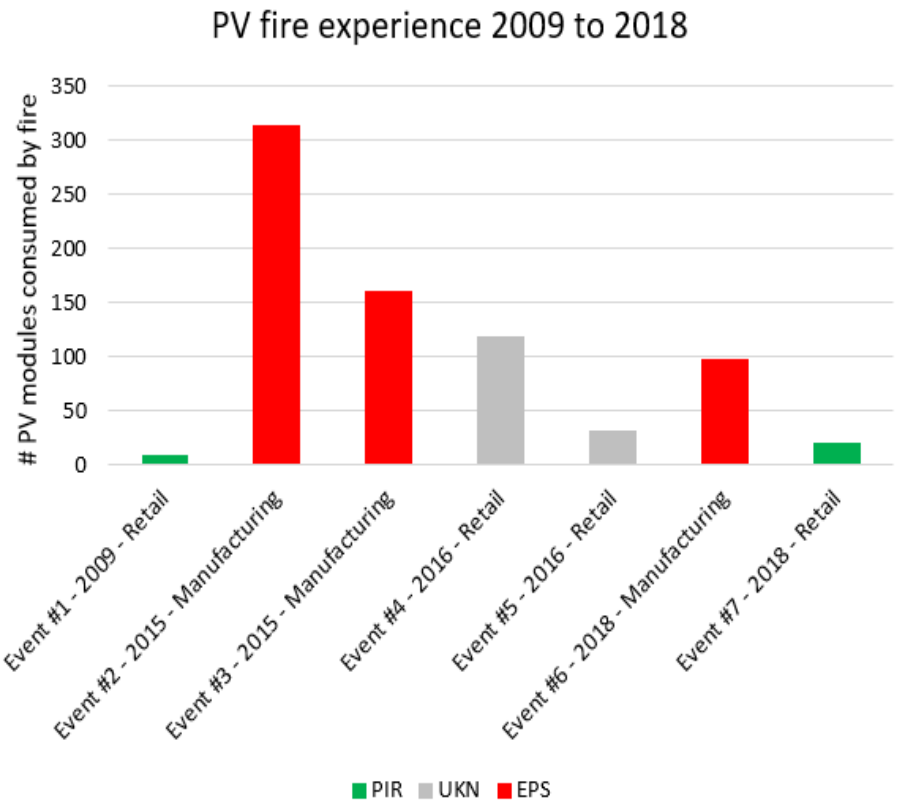


(Photo source: Rich Gallagher, The Zurich Services Corporation)

Limited industry experience

Fire

- Fire propagation observations
  - Bar chart shares data for 7 fires where
    - There was fire propagation in an array
    - The # of modules damaged was known
    - The building was not loss
  - **Red bars** – EPS or XPS roof insulation
    - Less favorable: 100+ modules per fire
  - **Green bars** - PIR roof insulation
    - More favorable: ≤30 modules per fire
  - **Gray bars** – Unknown insulation
    - Raises uncertainty
    - Is PIR always a more favorable
  - Highlights the need for large-scale fire research which is being pursued in 2020
    - NFPA Research Foundation managed
    - Property Insurance Research Group funded



EPS = Expanded polystyrene insulation
XPS = Extruded polystyrene insulation
PIR = Polyisocyanurate insulation
UKN = Unknown insulation

(Image source: Rich Gallagher, The Zurich Services Corporation)

Limited industry experience

Wind

- Zurich is aware of limited data from Super Storm Sandy (October 2012)
  - The data set included 7 installations with PV modules on ballasted racks
    - Those are racks secured with concrete blocks (see photo below)
  - 4 cases
    - Wind stayed below 65% of the recommended design wind speed
    - No signs of visible PV system damage
  - 3 cases
    - Wind exceeded 65% of the recommended design wind speed
    - There were signs of visible PV system damage such as
      - PV racks moved
      - PV rack ballast fell of the rack onto the roof cover
      - PV racks lifted
      - PV modules separated from racks

Information source:

Dregger, Phil. Field Survey - Rooftop Solar PV Performance During Hurricane Sandy. Technical Roof Services, 2012.

(Photo source: Rich Gallagher, The Zurich Services Corporation)

Limited industry experience

Wind

- A note on wind research
  - In 2014, IBHS* identified
    - A wind load paradox
      - While wind loads on buildings are greatest at the roof edge
      - Wind loads on PV arrays are greatest in the middle of the roof
    - PV systems are subject to dynamic wind loads
      - Static designs methods may under-estimate needed ballast
  - The above may explain the Super Storm Sandy findings

IBHS Large-scale wind lab (Richburg, SC)

Information source:

Photovoltaic Arrays: High Wind Research. IBHS 2014. https://ibhs.org/wp-content/uploads/wpmembers/files/Photovoltaic-Arrays-High-Wind-Research_IBHS.pdf

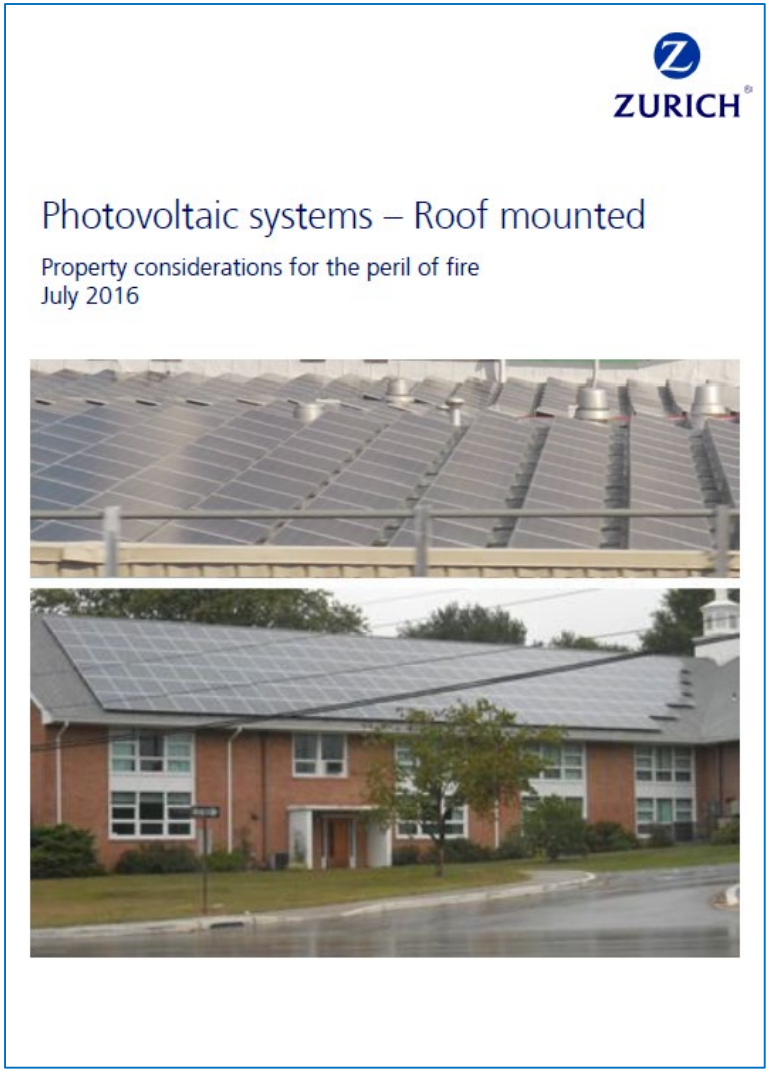
*IBHS = Insurance Institute for Business and Home Safety

(Photo source: Rich Gallagher, The Zurich Services Corporation)

CURRENT ZURICH APPROACH

Current Zurich approach

- White paper developed in 2016
  - It is focused on the peril of fire
  - It was based on very limited industry fire experience at the time
  - It addresses considerations for
    - Reducing likely fire inception hazards through
      - Design
      - Installation
      - Maintenance



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DEVELOPING INSIGHTS

Developing insights - fire

Summary of insights based upon limited industry experience

Favorable

- Roof surface
  - Gravel or concrete paver surfacing may resist fire
  - Metal may resist fire

Stone or gravel roof surface

Concrete paver roof surface

(Photo source: Tom Hall, The Zurich Services Corporation)

Developing insights - fire

Summary of insights based upon limited industry experience

Favorable

- Roof surface
  - Gravel or concrete paver surfacing may resist fire
  - Metal may resist fire
- Roof covers
  - Built-up covers may resist fire

Built-up roof cover

(Photo source: Tom Hall, Image Source: Rich Gallagher, The Zurich Services Corporation)

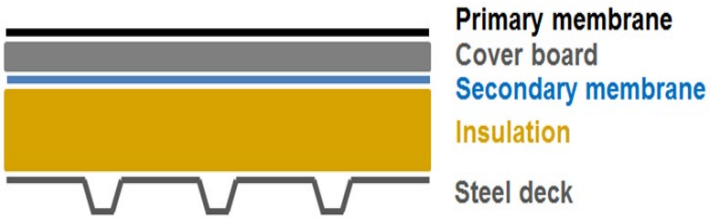
Developing insights - fire

Summary of insights based upon limited industry experience

Favorable

- Roof surface
  - Gravel or concrete paver surfacing may resist fire
  - Metal may resist fire
- Roof covers
  - Built-up covers may resist fire
- Roof insulation
  - Cover board is typical recommended to help keep fire from involving the roof insulation
    - However, polyisocyanurate (PIR) may be acceptable without cover board
  - Cover board may afford protection for a secondary membrane provided to help keep water out of the building below

Cover board (white) over PIR insulation (yellow or brown)



Cover board and secondary membrane

(Photo source: Tom Hall, The Zurich Services Corporation)

Developing insights - fire

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  - Cover board may afford protection for a secondary membrane provided to help keep water out of the building below
- PV system features
  - Multiple small inverter – May avoid faults shutting down all power production while also reducing the effort needed to locate a fault

Large central inverter – 500 kW

Multiple small inverters – 45 kW

(Photo source: Rich Gallagher, The Zurich Services Corporation)

Developing insights - fire

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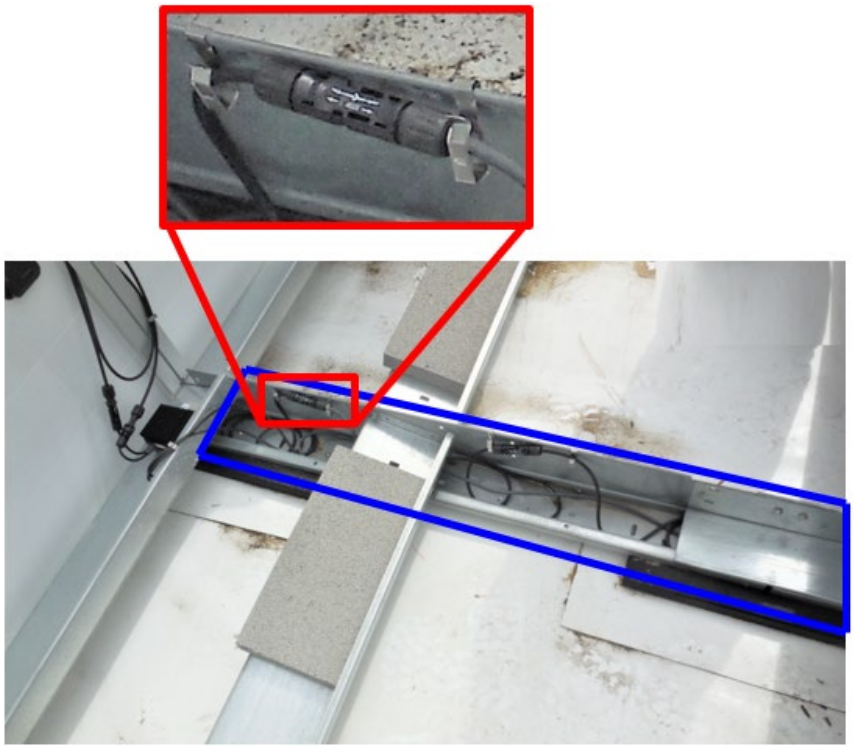
  - Multiple small inverter – May avoid faults shutting down all power production while also reducing the effort needed to locate a fault
  - Cable management features – May help avoid pinched PV system cables or water in connectors

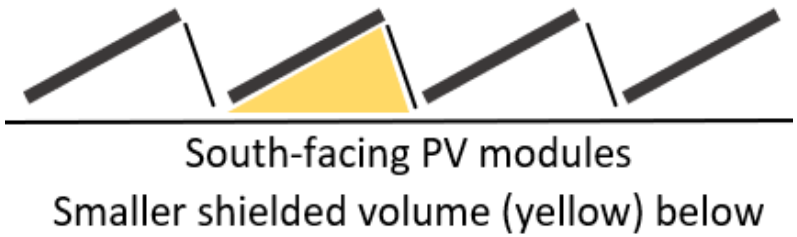


Red highlights metal clips holding cables away from pinch points and connectors above water
Blue highlights metal raceway to channel wiring

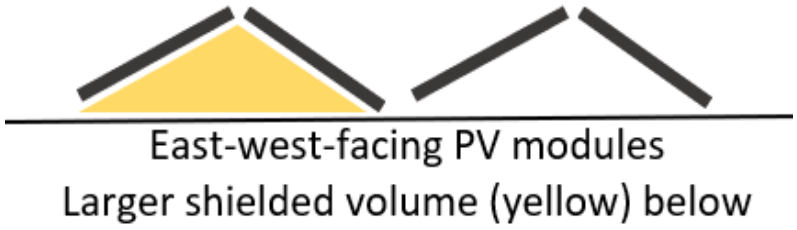
(Photo source: Rich Gallagher, The Zurich Services Corporation)

Developing insights - fire

Summary of insights based upon limited industry experience



South-facing PV modules
Smaller shielded volume (yellow) below



East-west-facing PV modules
Larger shielded volume (yellow) below

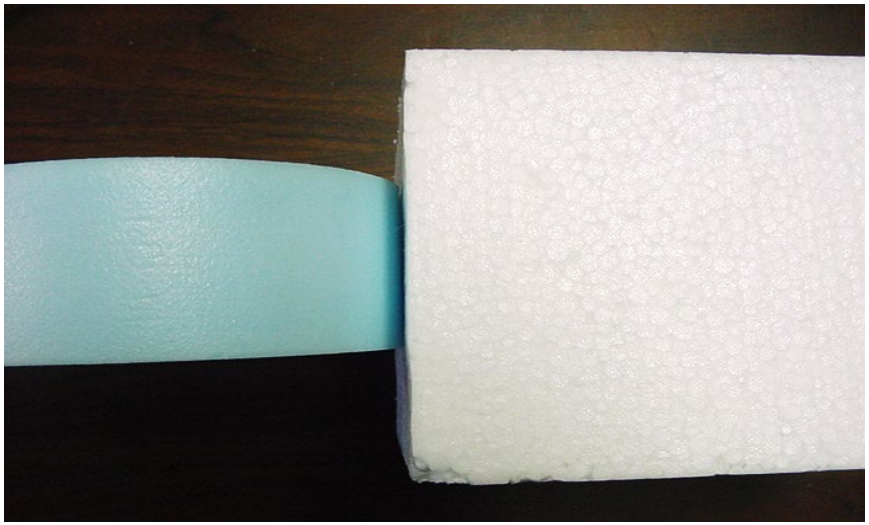
Unfavorable

- PV module configuration
  - Tented configuration may support larger fires

(Image source: Rich Gallagher; The Zurich Services Corporation)

Developing insights - fire

Summary of insights based upon limited industry experience



XPS (blue) and EPS (white) insulation

Unfavorable

- PV module configuration
  - Tented configuration may support larger fires
- Roof insulation
  - EPS or XPS is not considered acceptable in any amount anywhere in the roof

(Photo source: Tom Hall, The Zurich Services Corporation)

Developing insights - fire

Summary of insights based upon limited industry experience

Skylights

There is no established distance

Unfavorable

- PV module configuration
  - Tented configuration may support larger fires
- Roof insulation
  - EPS is not considered acceptable in any amount anywhere in the roof
- Roof penetrations
  - Keep PV modules away from skylights, roof drains, and expansion joints
    - These are features where a fire might spread into a building more easily

(Photo source: Rich Gallagher, The Zurich Services Corporation)

Developing insights - fire

Summary of insights based upon limited industry experience

Unfavorable

- PV module configuration
  - Tented configuration may support larger fires
- Roof insulation
  - EPS is not considered acceptable in any amount anywhere in the roof
- Roof penetrations
  - Keep PV modules away from skylights, roof drains, and expansion joints
    - These are features where a fire might spread into a building more easily
- Critical operations
  - Avoid PV systems on roofs over
    - High values
    - Production machinery
    - Automated systems
    - Hazardous operations

Developing insights - wind

Summary of insights based upon limited industry experience

Favorable

- Mechanically attach PV racks to the building structure (rather than securing with ballast)

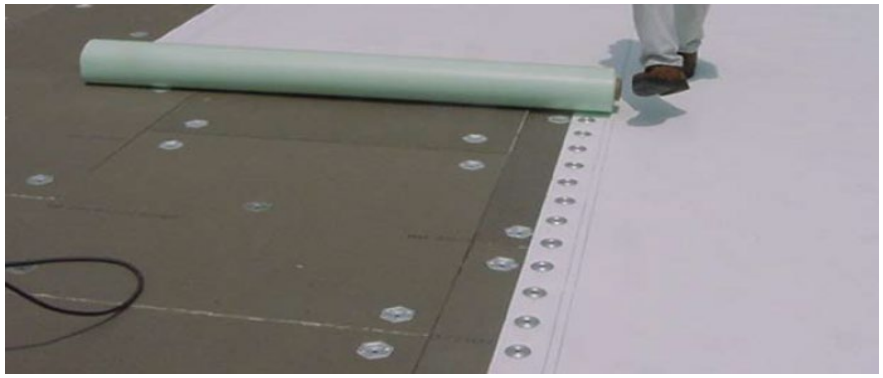
Stand-mounted PV system
Stands mechanically attached to the building structure

Ballasted PV system

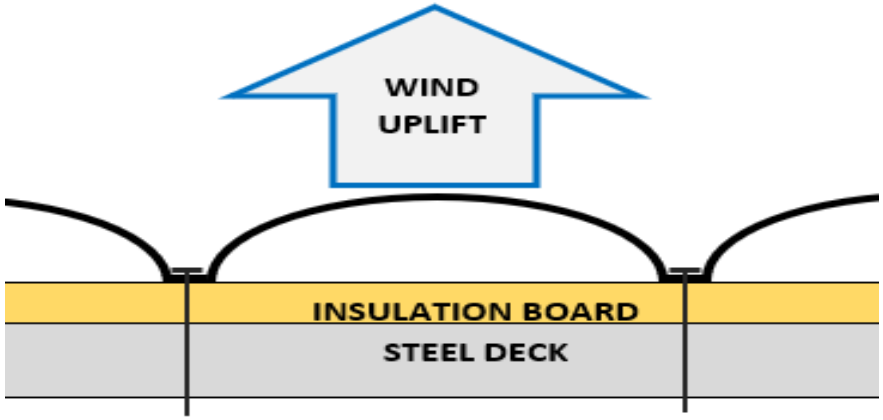
(Photo source: Top, Rich Gallagher; Bottom, David Williams; The Zurich Services Corporation)

Developing insights - wind

Summary of insights based upon limited industry experience



Mechanically fastened membrane being installed



Mechanically fastened membrane billowing upward between fastener rows

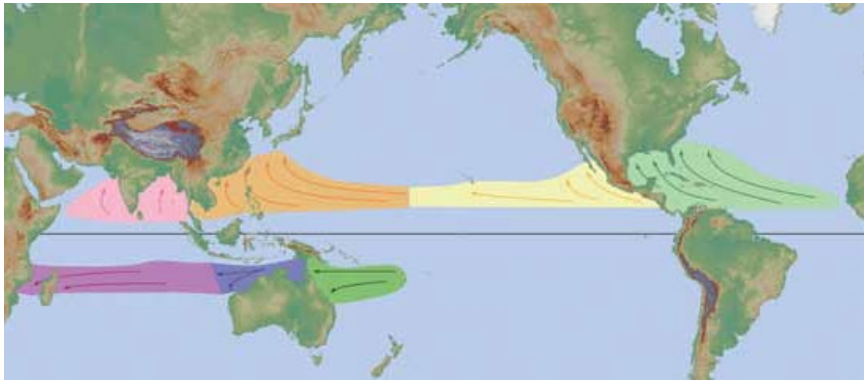
Unfavorable

- Avoid PV systems on mechanically attached single-ply membrane roofs
  - These roofs typically have fastener rows on 3 m (10 ft.) on centers. Between fastener rows, the cover is expected to billow upward when exposed to wind. PV ballast is not expected to prevent this upward billowing. When the roof cover billows upward, the PV racks may slide leading to system damage.

(Photo source: Top, Tom Hall; Bottom, Rich Gallagher; The Zurich Services Corporation)

Developing insights - wind

Summary of insights based upon limited industry experience



Hurricane regions - Atlantic and Gulf coasts + Hawaii

Unfavorable

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- Avoid PV systems in hurricane prone regions
  - Further PV wind research is being pursued and may offer better insights regarding PV systems in high wind regions

(Image source: US Dept of Commerce, National Oceanic and Atmospheric Administration, National Hurricane Center)

Questions

Thank you

Risk Engineering
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